THE POTENTIAL OF TERRESTRIAL CARBON SEQUESTRATION METHODS AS OPTIONS FOR CLIMATE CHANGE MITIGATION

Sarah Pittiglio
Office of Energy Research and Development
Environmental Area
California Energy Commission

Trina Filan
Office of Energy Research and Development
Environmental Area
California Energy Commission

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Abstract

A workshop was held in support of the *2009 Integrated Energy Policy Report* (*2009 IEPR*) to consider ways to capture carbon dioxide (known as "carbon sequestration") above- and below-ground in California to contribute to the carbon-reduction goal of Assembly Bill 32 (AB 32, Nunez, Chapter 488, Statutes 2006). AB 32 enacted the "Global Warming Solutions Act of 2006" which requires the adoption of regulations to reduce California's greenhouse gas emissions to 1990 levels by the year 2020. Various sequestration methods were discussed, particularly in reference to future cap-and-trade markets. Terrestrial carbon sequestration was discussed with respect to forest management, biochar (charcoal created from the chemical decomposition of biomass by heating at high temperatures), agriculture, wetland management, rangeland management, and the energy sector. Conclusions from this workshop substantiate the claim that there are several promising ways to capture carbon in California soils. Recommendations for future research include determining which rangeland management practices might be most advantageous for carbon sequestration. Future research in forest sequestration should combine management methods with a holistic approach in planning for climate change adaptation. Because the long-term efficacy of biochar applications varies with local conditions, it is important to examine how biochar behaves in different environments. In agricultural soils, more measurements need to be made to accurately model nitrous oxide emissions. Continued investigations are needed in wetlands to determine how to maximize carbon sequestration, protect water quality, and provide wildlife habitat. Rangeland research should focus on processes that improve the bottom line (productivity) first, since these are preferred by managers over those that focus on ecosystem improvement. Identifying which carbon sequestration protocols in California are the most efficient will be key. Research should focus on how best to support protocols that can be used in the national carbon market and those that can transition from voluntary protocols.

Keywords: Carbon sequestration, greenhouse gas, forest, biochar, wetland, rangeland, agriculture, carbon market, cap-and-trade, GHG emissions

1.0 CHAPTER 1: Opening Comments

Sarah Pittiglio

This workshop, in support of the *2009 Integrated Energy Policy Report* (*2009 IEPR*), considered the ability of above- and below-ground terrestrial carbon sequestration methods to contribute to the 2020 carbon-reduction goal of Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006), particularly in future cap-and-trade markets. Various sequestration methods, their efficacy, their regulation, and their significance pertaining to AB 32 goals were discussed.

Opening comments dealt with the history of climate change legislation in California and the California Energy Commission Public Interest Energy Research (PIER) Program involvement in climate change research and policy recommendations. The California Climate Change Center, a virtual research center, unites PIER with Scripps Institution of Oceanography (SIO) and most other major research institutes in California to do research a variety of climate-related issues including methods for GHG emissions reduction.

Greenhouse gas emissions can be reduced at their source or can be mitigated through sequestration and storage. Sequestration, especially of carbon dioxide (CO_2), can occur through geologic sequestration, increasing aboveground plant biomass, or increasing soil carbon stores. Current PIER-funded carbon-sequestration research includes

- Examining the carbon-sequestration potential of altering agricultural practices, including fertilization, tillage, and cover-cropping practices.
- Examining the carbon-sequestration potential of afforestation of Shasta County rangelands.
- Examining the carbon-sequestration potential of growing wetlands on islands in the Sacramento-San Joaquin Delta.

Funding has been set aside (and soon will be distributed) for a new collection of carbon-sequestration studies, which will include

- Accounting for the full sequestration potential of biochar,[1] which can be used to restore soil fertility and to store carbon for up to many centuries. Biochar has not been fully tested in California soils, nor have nitrous oxide or methane emissions from biochar-treated soils been measured.

1 Biochar is charcoal created from the chemical decomposition of biomass by heating at high temperatures.

2.0 CHAPTER 2: Carbon Sequestration Efforts in California's Forests

Tim Robards, California Department of Forestry and Fire Protection

This presentation provided an overview of how California's forest resources and forest management practices fit into the broad scheme of AB 32 and its carbon sequestration goals. Mr. Robards described carbon sequestration as turning atmospheric carbon into more complex molecules, such as those in the tissue of plants. There are a number of different forest carbon pools, including the live stem (bole); the crown, including the leaves and branches; the litter and duff (decomposed litter) on the ground; the roots and soil below ground; standing and downed deadwood; and the various end uses of wood, such as wood products, materials that end up in landfills, and biomass used for energy production.

Mr. Robards went on to describe the carbon cycle and the processes that affect this cycle, including surface energy fluxes, hydrology, vegetation dynamics, and conversion of forest lands to other land uses, such as agriculture or urbanization. These processes may have either positive or negative effects on the carbon sequestration process, thereby enhancing or utterly undoing it, respectively. Forests are important both to increasing atmospheric carbon (through their removal) and to potentially reversing trends in global warming. The Intergovernmental Panel on Climate Change (IPCC) has estimated a 35% increase in atmospheric CO_2 in the industrial era due primarily to combustion of fossil fuels and removal of forests (primarily tropical, but also temperate and boreal).

California forests cover nearly one-third of the state's land base; urban forests cover 5 percent of the land base. The state's forests provide a number of economic services, including water and wood products provision and recreation, as well as ecosystem services, such as the storage of 8.5 billion tons of CO_2. Mr. Robards offered a breakdown of how much CO_2 is stored in the state's various public and private forestlands and in each part of the forest carbon pool.

Mr. Robards then discussed various forest management methods and ways to avoid deforestation as well as to make progress on reforestation and afforestation (planting forests in formerly non-forest systems, such as grasslands and rangelands) efforts. He also discussed the evolution of forest management practice in the state, from the belief in fire suppression to the desire to avoid micromanaging forest systems.

The potential for carbon sequestration was covered, as well. In reflecting on AB 32, the concept of no net loss offers various means of meeting emissions goals: through growth of forest stock, maximizing sequestration, or protecting existing stocks. Each has its concerns and drawbacks, and it must be remembered that aboveground stocks can take a hit either by disease or fire and thereby can become losses to the system. Because no one method will adequately address the goals of AB 32, a combination of management methods and a holistic approach, combined with planning for adaptation under climate change, are all necessary. A combination approach would allow forest assets to be simultaneously protected and enhanced.

Under the AB 32 *Scoping Plan*, there are five strategies for carbon sequestration in forests: conservation, forest management, reforestation, afforestation in urban areas, and fuels management. Getting all of the strategies coordinated required state and federal agency cooperation and measuring the progress of inventory and monitoring. The Interagency Forestry Working Group (IFWG), which is composed of a variety of state and federal agencies, will offer recommendations and technical advice to the Board of Forestry for it to achieve AB 32 goals and to outline forest adaptation strategies. IFWG principles and its progress can be tracked at www.bof.fire.ca.gov.

More state forest policy goals include dealing with the cap and trade program, the Western Climate Initiative, the revised Climate Action Reserve protocols, the revised forest sector inventory, as well as national- and international-scale considerations.

Questions from the audience included one regarding what counts as forestland: timberlands that are comprised of conifer commercial species are not counted, but oak savannah and rangeland with more than 10 percent canopy cover are. Riparian zones in valleys also might count, depending upon their capacity for reforestation or afforestation. Another question concerned methane release from standing wood decomposition, which Mr. Robards could not adequately answer (but neither has existing science). A final question concerned CO_2 emissions from wildfires, which apparently are estimated using California Air Resources Board models, but are not totally accurate, given the set of assumptions upon which the models are predicated.

3.0 CHAPTER 3: The Carbon Sequestration Potential of Biochar Amendments

John Moussouris, VenEarth Group LLC

This presentation introduced and delineated the efficacy of using biochar — charcoal produced by pyrolysis[2] of biomass —as a means of sequestering carbon in various ecosystems, particularly in agroecosystems.

Biochar was used by pre-Columbian indigenous populations in the Amazon Basin as a means of increasing soil fertility; it has a soil residence time of many hundreds and up to thousands of years, and its carbon concentration is 20% compared to 3% in the surrounding untreated soil. This soil is very fertile and has high biodiversity and good structure. Its high carbon concentration has generated excitement about its potential to be used in sequestering atmospheric CO_2 in a self-sustaining way.

Through a series of calculations that include the amount of carbon currently in the atmosphere, the amount that needs to be taken out of the atmosphere, the efficiency of pyrolysis in converting atmospheric carbon into biochar, and the amount of appropriate landmass (primarily agricultural land and grazing land) required to incorporate the biochar generated, among other variables, it was found that about 3 tons of biochar per hectare for 50 years incorporated into the topsoil would sequester enough carbon to counteract global warming.

Further calculations estimate the amount of raw biomass required to produce this amount of biochar at 18 tons per hectare. While tropical forests where shifting cultivation is done easily can produce this much biomass (20 tons per year), temperate forests and cropland produce much less (12 tons and six tons, respectively), unless specialized crops like miscanthus are used (30 tons), which is not an advisable diversion of land use. Therefore, additional sources of biomass must be found for temperate croplands. These additional sources can include animal manures, land management wastes, bio-industrial wastes, and municipal wastes.

There are some existing technical issues with biochar production, aside from the acquisition of enough biomass and appropriate land area for creation and application of biochar, primarily making the process energy efficient, even energy generating, and making sure the process can occur on a local level, rather than needing to transport biochar to outlying areas, which would diminish its AB 32 applicability. Biochar generation can be coupled with solar greenhouses both to sequester carbon and to generate energy to replace fossil fuels.

Biochar has other benefits, as well, including its applicability to non-crop lands and to suburban and urban areas; its ability to enhance soil water retention; its ability to improve the health of animals when added to feed; its ability to enhance soil biodiversity; and its longevity in soils.

The presentation concluded with examples of local-scale biochar operations and their success rates in a number of different developing and developed nations. The technology has potential

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2 The chemical decomposition of organic matter in the presence of high temperature and no oxygen.

to help reduce global climate change, but more research must be done to develop protocols that will assure it is done properly according to the setting in which it is undertaken. Different soils, regions, types of biomass, and methods of biomass conversion all will affect the long-term efficacy of biochar applications.

4.0 CHAPTER 4: The Role of Agriculture in Reducing Greenhouse Gas Emissions

Johan Six, University of California, Davis

While the previous presentation focused on large-scale carbon-sequestration potentials for agricultural lands, this presentation elaborated on some smaller-scale options for carbon sequestration on agricultural lands. According to a 2005 California Energy Commission study, agriculture and forestry are responsible for only 8% of GHG emissions in the state, so the potential impact of GHG reductions in this sector is not huge, unless the sector can become a carbon sink, as well. Nonetheless, there is some potential to reduce GHG emissions.

First, GHG reduction in agriculture does not refer solely to CO_2, but also to methane (CH_4) and nitrous oxide (N_2O). N_2O accounts for about 50% of GHG emissions in agriculture. Sources for N_2O include fertilizer, crop residues, and manure; there are no soil sinks, so reduction is the only mitigation option for this compound. Sources for CO_2 include fossil fuels, biomass burning, and soil degradation; sinks include soil organic matter build-up and plant biomass. Sources for CH_4 include livestock, manure, and anaerobic soils (such as where rice is grown); sinks include aerobic soils, especially forests and grasslands.

Mitigation options for agriculturally derived GHGs include alternative agricultural practices, such as reduced or zero tillage, use of winter cover crops, adding more hay into crop rotations, using higher above- and below-ground residue-yielding crops, applying manure rather than chemical fertilizers, and organic cropping. Employing set-asides or conversions of agricultural lands to perennial grasses also are useful in mitigation.

Research was done throughout the Central Valley to see which of the above-listed practices show the greatest potential for GHG emission reduction on a regional scale. Emissions under alternative practices were compared with emissions under conventional practices; if, when the latter is subtracted from the former, a negative number is achieved, then reduction of GHGs has been successful.

Research is based on a model into which measurements of pertinent variables are input over the time of the experiment; this continual inputting of data is done both to validate the model and to add to its effectiveness. Remote sensing also was added to the model to improve it by adding spatial and temporal variability in crop growth and production.

Dr. Six discussed the methods used to test the DAYCENT model[3] vis-à-vis the measured data collected from four longer-term research sites; calculations show that the model has about a 90 percent predictive level. The model shows, at the site level, some small amount of mitigation potential when standard tillage and organic practices are combined. It is important to remember there will be seasonal variation based upon wet/dry and hot/cool climate. Further modeling shows that conservation tillage and cover cropping have a mitigating impact, at least in part

3 The DAYCENT model is a land surface model that simulates soil N_2O, NOx (nitrogen oxides), and CH_4 fluxes for terrestrial ecosystems.

due to the reduction in fuel use that accompanies conservation tillage practices. These practices do not seem to affect the N_2O emissions, which should be the target emissions.

At the regional level, cover cropping and manure additions seem to provide a level of carbon ersequestering, but the Sacramento Valley has better sequestration potentials than the San Joaquin Valley, mostly due to temperature differences. Nitrous oxide levels, again, were not greatly affected by alternative practices. Ultimately, reducing N_2O will come from not adding fertilizers in the first place: What does not go in does not need to come out. Permanence of the mitigation, additionality (as in, is sequestration an additional benefit of a practice or something that would have happened anyway), and leakage (for example, mitigating in one area but compensating for loss of productivity by farming in another area) are all variables that add uncertainty to the model.

Nitrous oxide is the big unknown in the whole process; the question is how much can fertilizer application be reduced without affecting crop yields, a question that is difficult to answer as long as farmers are unwilling to "experiment" with their own yields. This obstacle requires outreach to farmers and education about the effects of overfertilization versus the risks they are trying to reduce by overfertilizing to begin with.

It also will be important to deal with perennial systems, such as vineyards and orchards, to continue monitoring existing experimental sites and to create and enhance with new information a decision-support tool for stakeholders (COMET-VR).

Lay articles are available at http://californiaagriculture.ucanr.org/.

One questioner asked what types of fertilization methods were compared. Dr. Six replied that a split application method was used, with reduced amounts of fertilizer over different splits. The model does not yet have the capacity to account for different application methods.

5.0 CHAPTER 5: Reforestation and Other Terrestrial Sequestration Opportunities in California

Katie Goslee, Winrock International

This presentation expanded on the topic covered in the first presentation, the potential of forest management and forest-related projects for carbon sequestration, a potential that is relatively high and has several benefits in addition to sequestration, especially if the system is not just managed for one function but, rather, for many. Forest management can mean anything from changing rotation length to leaving slash in the forest after harvest; from extending and replanting riparian zones to changing the volume that is logged to assessing the types of wood products for which management is done.

Ms. Goslee provided some examples of amount of potential carbon sequestration and dollars saved by California county by lengthening harvest rotation by five years. The least expensive counties in which to implement this practice did not necessarily yield the greatest carbon off-sets; cost trade-offs will have to be addressed for this scenario. However, when extending riparian buffers was added to the strategy of lengthening harvest rotations, least expensive counties did sequester more carbon. Cost trade-offs of multiple, intersecting scenarios will have to be considered.

Forest conservation projects offer another route to carbon sequestration, whether these projects involve avoided conversion or developing conservation initiatives; however, baselines for forest conversion, which are difficult to establish, are still being identified through collaboration with the PIER Program. Reforestation and afforestation[4] are two means of conservation that will be examined in this discussion. From various studies performed by Winrock, afforestation and reforestation seem to have greater carbon sequestration potentials than other forest management options, but these potentials take a long time to be realized (due to tree growth and maturation time) and vary greatly depending on species composition.

Maps showing potential tons of carbon per hectare and potential cost per ton of carbon for afforestation projects throughout California were shown. Again, least expensive areas do not necessarily correspond to highest sequestration potentials. At $13.6 per ton of carbon, it is possible to sequester 3.4 million metric tons of carbon dioxide in 20 years. In looking at rangelands most appropriate for afforestation or reforestation projects, Winrock found approximately 23.6 million acres of current rangeland highly suited to the process.

Winrock has been doing pilot projects at various sites on private land in Shasta County. There are a total of 12 projects covering 470 total acres, all are small-scale, and all required extensive outreach to and education of landowners to get buy-in for the projects. Site preparation,

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4 Reforestation, in this case, is considered planting trees on lands that were in forest cover within the last 50 years, whereas afforestation is planting trees on lands that were in forest cover more than 50 years ago.

acquiring individual site baselines,[5] and modeling growth also are factors that added time to these projects. Rates of carbon accumulation are being modeled using the Forest vegetation Simulator; these models will be adjusted during Year 2 or 3 of each project to account for seedling survivorship.

Costs to consider for this — or any — type of carbon management project includes establishment costs (including site preparation, purchase of seedlings, and acquisition of easements), maintenance costs (including continued viability of seedlings), measurement costs for establishing baseline and growth over time, and lost opportunity costs to account for what the land would otherwise have been used for. These latter costs seem to be the greatest challenge both economically and emotionally for the landowners (up to 79% of the cost in previous projects in the southeastern United States).

As far as policy is concerned, regulations should focus on offsets rather than on land use or forest management practices. Offsets should be real and additional, and an emphasis should be placed on the benefits of these projects.

An audience member asked if there are ways to give land owners the economic benefits up-front, as is being done in Australia. Ms. Goslee does not know of any similar efforts. Buyers of offsets are looking for already-sequestered tons rather than "to be" sequestered tons.

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5 Baseline is tons of carbon dioxide per acre prior to site preparation. Baseline is based on existing vegetation, often shrubs, which have different lifespans and carbon dioxide sequestration potentials than trees. Acquiring accurate baselines is, therefore, difficult.

6.0 CHAPTER 6: Carbon Sequestration in Managed Wetlands: Status of an R&D Effort to Determine if They Are Appropriate for Carbon Credit Investments

Kim Taylor, USGS

This presentation dealt with a long-term U.S. Geological Survey (USGS) project in the Sacramento-San Joaquin Delta (the Delta) relating to reversal of land subsidence through biomass accretion and the concomitant benefit of carbon sequestration. The biomass in question is root material that is very hard and has been dubbed proto-peat; it will turn into peat (the oxidation of which has been the root cause of subsidence since land reclamation began in the Delta in the mid-1800s) over several thousand years.

Research on Delta subsidence has gone on for more than 20 years; subsidence is an issue for those concerned about water quality, water supply from the Delta, and the quality of aquatic habitat throughout the Delta. Some islands in the Delta have experienced subsidence up to 25 feet below sea level, and ongoing subsidence of a few inches a year continues apace. Subsidence due to microbial oxidation of peat soils stops only when the soils are completely and continually flooded with water. The question has become: If subsidence can be stopped, can it be reversed?

To test the question, two pilot sites were established in 1997 on Twitchell Island; the areas were leveled, and pumping of water out of the island soils was stopped to allow flooding to two different depths. Then tules and cattails were planted. A number of different measurements were taken and studies were done to determine how various ecosystem processes were functioning. Over time, the two sites were seen to be evolving differently: The site with shallower water was homogeneous in plant and other species distribution and water flow; the site with deeper water was heterogeneous in plant and other species distribution and water flow rates and pathways. From these two systems, in comparison with surrounding agricultural land uses, 30 tons more carbon dioxide can be captured per acre by wetlands than by agricultural land on which corn is grown.[6] The highest potential sequestration for these areas is at the high end of all land-use sequestration potentials; the low end is still higher than the high end of the best land use practice, marsh lands.

This biomass accretion was slow but steady for the first seven years of the project, after which time it jumped considerably. This time lag must be noted in the context of policy-making, which tends to hinge upon the satisfaction provided by immediate results rather than slow and steady study.

These results might be explained by a combination of lower decomposition rates (due to a reduced amount of dissolved oxygen in the water) and higher plant growth (due to increased uptake of nutrients), which combined lead to minimal methane emissions and increased carbon dioxide sequestration. One caveat that needs to be examined is that open water areas have

6 Corn was used as the baseline for this study.

methane emission, and research needs to examine why this is in relation to these wetland areas with high sequestration rates.

Current PIER-funded research seeks to establish a baseline for GHG emissions (in the form of methane) for established wetlands and seasonally flooded areas, the latter of which could be off-the-charts in terms of emissions. Seasonally flooded corn fields will serve as baseline indicators; measurements are taking place during the summer of 2009.

The research also will look at flow rates; different plant communities and their effects on the system; effects on the system of sediment amendments; the process of mercury methylation in the system; the effects of dissolved organic carbon on water quality; and types of carbon coming out of the system. Sequestration efficacy and heterogeneity going into the future will be modeled using the Denitrification-Decomposition (DNDC) model. The goal of the project is to have these managed wetlands be viable on the carbon credit market, but there are other goals, such as examining economies of scale (from farm to region), determining efficacy of managed wetlands to mitigate levee failure, and determining costs related to hazard planning and recovery programs.

Questions from the audience include trying to understand the mechanism behind the emissions of carbon dioxide from corn fields (These are mostly due to soil oxidation and to seasonal flooding of crop land.); whether other cash crops might be useful for eliminating these emissions (there are rice trials going on in the north Delta to see whether rice can be used to sequester carbon); how 40 tons of carbon dioxide can be sequestered per year. (Biogeochemical tests are ongoing to determine why there was a sudden and continual annual spike in sequestration rates and how those rates can be recreated.)

7.0 CHAPTER 7: Rangeland Soil Carbon Sequestration in California: Challenges and Opportunities

Andrew Fynn, C Restored LLC

Rangelands are uncultivated land where native vegetation is mostly grasses and grasslike species. Pastureland is different in that there is periodic cultivation and agronomic inputs, such as irrigation and weed control, to maintain introduced forage species. There is some issue, as well, in distinguishing where rangeland ends and forestland begins.

In California, there are about 63 million acres of rangeland; of this, about 57 million acres is primary rangeland (which excludes upland forest), of which about 41 acres is available for grazing. Grazing is the main project action category that affects carbon sequestration in aboveground biomass in rangelands. In the state, all grazing land totals about 84.1 million acres. Of all rangelands, chaparral and deserts comprise the highest acreage, but these areas might be better suited to avoiding carbon emissions rather than promoting carbon sequestration, due to their fragility.

Rangeland carbon is composed of soil carbon (organic and inorganic) and (woody) biomass carbon. Soil organic carbon, as was shown with the biochar presentation, is the ultimate goal for a win-win scenario of sequestration and increased soil fertility. The soil carbon balance can be managed directly through inputs and outputs or indirectly by affecting the processes of carbon accumulation. Research still needs to be done on the sequestration potential of limiting erosion and weathering of inorganic carbon from calcic soils.[7] Much more is known about soil organic carbon sequestration from a variety of management practices. For example, pasture cropping[8] seems to have some sequestration benefits, as does rangeland, woody species, and riparian zone restoration.

Past studies on California ecosystems as carbon sources or sinks are used to inform the research presented in this discussion. Dennis Baldocchi found that oak woodlands are carbon sinks and grasslands are carbon neutral, but rain triggers carbon output from these systems; grasslands are more variable than oak woodlands. Wendy Silver found that compost additions to grazing lands enhanced carbon sequestration, and use of a keyline plow created the lowest carbon emissions from the subsoil. Monitoring at these sites is ongoing.

Despite this research, little quantification of the effects of management practices on rangeland soil carbon has been done. For example, management-intensive grazing, a preferred management practice by rangeland managers around the country, has had little soil carbon research done on it. Research should focus on processes that improve the bottom line (productivity) first, since these are preferred by managers to those practices that focus first on ecosystem improvement. Coordinated research efforts would help to fill gaps in knowledge.

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7 Soils rich in calcium carbonate deposits.

8 Pasture cropping involves planting a cereal crop during the non-grazing season to minimize exposure of bare soil to the elements.

Research also needs to be done to see how nitrogen sequestration through planting of legumes might work in conjunction with carbon-sequestration methods.

How will rangeland carbon credits be regulated under a cap-and-trade system? There is a spectrum of methods from the simple to the complex; from the rapid to the lengthy; and from the cheap to the expensive. Credits must be real, permanent, quantifiable, verifiable, additional, and enforceable, according to the California Air Resources Board. The key seems to be in the middle of each of these spectra, a balance that will involve compromise and a move from the theoretical to the actual. Integrated collaborative research in three phases to 1) establish a baseline soil carbon mapping throughout the state, 2) assess best management practices, and 3) implement coordinated, targeted research on areas of greatest potential and uncertainty might be a place to start. Landowner participation will be crucial. A panel responsible for protocol development and maximizing mitigation potential will manage the collaboration.

With such a comprehensive, integrated method in place, it might be possible for rangeland carbon sequestration to contribute 14% of AB 32 emissions reduction targets with only a 1% absolute increase in soil organic matter content to 50 cm depth (this goal might take 100 years to achieve). Rangeland carbon credits can be secured for 100 years using many of the same protocols used to secure forest carbon credits.

Ultimately, the expanse of rangelands in California combined with the amount of soil organic carbon in those rangeland soils provides an immense opportunity for carbon sequestration with even minor changes in soil carbon amounts; this scenario is a win-win, as mentioned.

8.0 CHAPTER 8: The Role of Terrestrial Carbon Sequestration in the Energy Sector

George San Martin, Pacific Gas and Electric (PG&E) Climate Protection program manager

This presentation provides the perspective of a company that desires to procure offset credits, which PG&E views as a significant potential cost-containment mechanism. (Other options for compliance with cap-and-trade for companies under such regulations include purc.hasing allowances and reducing their own emissions.) The five most likely offset categories are agricultural waste, forestry, fugitive emissions from coal mines and other sources, landfill gas, and soil sequestration.

The most likely carbon pipelines for the voluntary market, according to PointCarbon,[9] are forestry, soil sequestration, and agricultural wastes. As of 2012, there will be only about 12 million tons of carbon offsets on the voluntary market, but with regulatory structures coming into place that have some teeth and compliance requirements, that number is likely to increase substantially. There is a maze of domestic offset standards at the national, regional, state, and local levels for companies to wade through.

Some believe that domestic offsets will not be large enough to satisfy demand in the coming years. Demand for these offsets will depend on how they compare to other compliance options as far as price is concerned, and they will also be compared to international offset options. At the beginning of a cap-and-trade program, domestic offsets likely would be more attractive, while other options that are only conceptual now might be more attractive as time passes.

PG&E has a program called ClimateSmart, which is a way for the company to look at how energy and climate can be managed as part of the company's entire portfolio of solutions. In this framework, energy efficiency/demand response, renewable power supply, and ClimateSmart options all impact upon each other in a continually iterative cycle.

ClimateSmart is a voluntary program to make customers climate neutral. It also is a way to road test current and new Climate Action Reserve (CAR)[10] protocols and to fund the development of CAR protocols. ClimateSmart offers PG&E a chance to invest in projects that reduce GHG emissions, which means it might be able to invest in research to fill gaps in knowledge such as those mentioned in previous presentations.

ClimateSmart involves a commitment by PG&E to reduce its carbon dioxide emissions by 1.5 million tons over the course (time frame not mentioned); therefore, PG&E has an interest in

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9 PointCarbon provides carbon price forecasts and analysis of GHG emissions trading markets.

10 The Climate Action Reserve is a national offsets program involved with the U.S. carbon market. It establishes regulatory-quality standards for the development, quantification and verification of greenhouse gas (GHG) emissions reduction projects in North America; issues carbon offset credits known as Climate Reserve Tonnes (CRT) generated from such projects; and tracks the transaction of credits over time in a transparent, publicly-accessible system.

finding and demonstrating in the marketplace the best GHG emission reduction projects. There is a competitive bidding process involved, and only California projects are eligible.

The process follows this path: A household signs up for ClimateSmart and calculates its carbon footprint; PG&E contracts with a project that will offset this footprint. Offsets can come from forestry projects, dairy methane capture, urban forestry, and landfill methane capture, among other options. Businesses are also welcome to apply for the program. The project also examines the carbon footprint of individual appliances and other sources of emissions. Ultimately, ClimateSmart seeks to educate people about offsets and their direct application to customers' lives.

Offset supply will be a key price driver until 2030. Identifying which offset protocols are most efficient in California will be key. Embracing uniformity will be good for industry. Hopefully, the projects discussed in this session will be carried forward, along with other research, to influence and to support CAR protocols, protocols that can be used in the market and that can transition from voluntary protocols. It would behoove California to be able to influence federal protocols and ultimately to have sequestration within California to be paid for by users outside California.

Questions from the audience included a request for clarification about the types of offsets PG&E is interested in (They are focused on voluntary offsets, but in the future, offsets likely will be allowed on the compliance market, as well.) and whether ClimateSmart would end when federal cap-and-trade guidelines came into play. (It would not necessarily end, as it might continue to serve the role of demonstrating most-viable offset solutions.)

9.0 CHAPTER 9: Open Discussion on Terrestrial Carbon Sequestration Methods — Summary

John Mount, a forest resource manager with Southern California Edison based at Shaver Lake, wanted to comment on the potential for carbon sequestration on forested lands. He believes the estimates and assumptions provided by the speakers are a bit low. He believes the potential for sequestration is tremendous but that actual forest management is a key to attaining those potentials. He believes fewer rather than more rules guiding forest management, as well as market forces that allow landowners to receive dollars for their services are both important points to bring up. The difference in success between voluntary and mandatory programs is the landowners themselves, who would prefer voluntary participation that does not require them to follow a bunch of rules. Further, removal of billions of tons of excess fuels would reduce fire hazard and increase sequestration by potentially adding wood products to the construction industry. Increasing stand diameter by removing small trees and promoting proscribed burns also would help, as would afforestation and getting long-term commitments from companies willing to invest in planting and maintaining stands.

Abe Doherty from the California Coastal Conservancy spoke in favor of research to determine the efficacy of tidal wetlands as carbon offsets, which are threatened by inundation by sea level rise, and which might be restored in a way that will make them carbon sinks.

Mara Kraus of the USGS wanted to know how nitrous oxide and methane can be brought into the aboveground sequestration and GHG emission-balance picture. **Johan Six** responded by saying the question was important, but that measuring carbon salts is easier than measuring N_2O and CH_4. There is huge spatial and temporal variance in these emissions, which means some modeling will always have to accompany chamber measurements, which alone would be cost prohibitive. Integration of measurements to calibrate and validate the model, along with continual monitoring will be the best way to proceed.

Mark Vayssieres from California Air Resources Board wanted to register his interest in biochar, especially because of its permanence, but the whole "how it can be done" aspect needs to be thought through more. How do you convince farmers that they want to do it? The actual agronomic advantages and implementation logistics have to be measured and figured out. It seems like it would be better to have it decentralized than having to transport it. **John Moussouris** responded by saying that biochar has the potential to be self-financing, especially in California, where there is so much sunshine and the desire for a product with high agronomic value. Making biochar involves more than just throwing waste into a stove and getting a useful product out; it takes skill to make it, like wine or beer. Demonstrating efficacy and profitability is going to be the key to widespread adoption. The economics also work out, even when rudimentary technology is used to build the stove. **Sarah Pittiglio** of the California Energy Commission also added that the Energy Commission has funded small-scale, on-farm projects that have demonstrated the potential to decentralize or create cooperatives around a biochar operation. **Mr. Moussouris** added that biochar operations are advantageous because they can be scaled to a local level. Making char doesn't require the energy input or scale that bioenergy requires, for example.

Mr. Moussouris then asked Andrew Fynn regarding the ratio of carbon to nitrogen in soils and the various conversion rates thereof. **Mr. Fynn** replied that the ratio is just the ratio, not the mitigation effect of sequestered carbon and nitrogen. The net effect of nitrous oxide on the amount of soil nitrogen in the cycle is not known at the moment.

No other verbal comments were given.

10.0 CHAPTER 10: Conclusions on Terrestrial Carbon Sequestration Methods and Recommended "Next Steps"

Conclusions from this workshop on terrestrial carbon sequestration methods substantiate the claim that there are several promising ways to sequester carbon in the soils of California. Below is a list summarizing the major research objectives identified in this IEPR workshop.

- Determining which rangeland management practices might be most advantageous for carbon sequestration in both soil and vegetation.
- Regarding sequestration methods in forests, no one method will adequately address the goals of AB 32; a combination of management methods and a holistic approach, combined with planning for adaptation under climate change, are all necessary. A combination approach would allow forest assets to be simultaneously protected and enhanced. Future research should investigate this multi-method approach.
- Biochar amendments have huge potential for sequestering carbon and reducing GHG emissions from soils. Different soils, regions, types of biomass, and methods of biomass conversion all will affect the long-term efficacy of biochar applications. Therefore it is important to examine how biochar behaves in different environments.
- In agricultural soils, nitrous oxide emissions are largely unknown. More measurements need to be made to accurately model these emissions. It also will be important to deal with perennial systems, such as vineyards and orchards, to continue monitoring existing experimental sites, and to create and enhance with new information a decision-support tool for stakeholders.
- Wetlands not only provide an opportunity for carbon sequestration, but also protect water quality and provide wildlife habitat. Continued investigations are needed to determine how to best manage these areas to maximize these potentials.
- Carbon sequestration in rangelands has only begun to be analyzed in the past couple of years and has shown great potential, especially given the large acreage of rangeland in California. Research should focus on processes that improve the bottom line (productivity) first, since these are preferred by managers to those practices that focus on ecosystem improvement. Coordinated research efforts would help to fill gaps in knowledge. Research also needs to be done to see how nitrogen sequestration through planting of legumes might work in conjunction with carbon-sequestration methods.
- Identifying which carbon sequestration protocols, or combination of protocols, that are most efficient in California will be key. Research should focus on how best to support CAR protocols, protocols that can be used in the market and that can transition from voluntary protocols.